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Global experience with jatropha cultivation for bioenergy: An assessment of socio-economic and environmental aspects

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ABSTRACT

This is an assessment of key economic, environmental and social issues pertaining to jatropha biofuels, based on almost 150 studies covering 26 countries. The assessment aims to furnish a state-of-the-art overview and identify knowledge gaps. So far, total jatropha production has remained small. Numbers and value of jatropha projects have even declined since 2008.

The economic analyses indicate minimal financial feasibility for projects. Yield increase and value addition (e.g., through utilising by-products) are necessary. Plantations seem to fare the worst, mainly due to the higher financial inputs used in a plantation setting and the still limited yield levels. Smallholders can only achieve financial feasibility in low-input settings and when opportunity costs are low. Unfortunately, hardly any Cost Benefit Analyses (CBA) are based on real data; partly due to a lack of long-running jatropha projects.

The environmental impact varies greatly across locations. Most studies indicate significant Greenhouse Gas (GHG) benefits over fossil fuels; however, this is only achieved with limited inputs and no loss of high C-stock biodiversity. The determinants in Life Cycle Analyses (LCA) are yield, input level, by-products utilisation, transesterification, transport distances, and land cover. More LCA research is required with more accurate data, and focusing on nitrous oxide emissions and the relation between production intensity and biodiversity impacts.

Minimal negative social impacts have been revealed so far, but discontinuation of projects affects communities through income losses and fostering more negative attitudes towards new projects. Moreover, hardly any studies quantify social impact comprehensively. Detailed data collection is necessary, involving baseline studies to start with.

If its financial feasibility is improved, jatropha can still become an option for sustainable energy production, GHG mitigation and rural development, especially through smallholder models. Successful implementation requires careful advance assessment of local circumstances, such as the political climate, gender aspects and land ownership structures.

Contents

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1. Introduction

Jatropha (*Jatropha curcas* L.) is being promoted as a potential renewable energy source as the tropical woody perennial tree or shrub species may survive in harsh climate and soil conditions. The current potential for producing jatropha biodiesel in arid and semi-arid areas in eight countries in Sub-Saharan Africa can be as large as 600 PJ yr^{-1} [1]. Furthermore, it is listed by the IPCC[1] as one of the potential bioenergy crops, with estimated costs of around 3.2 US $ GJ^{-1} [2]. However, there is insufficient knowledge about some of the agronomic, socio-economic and technical aspects of the jatropha value chain and its implications for the sustainable livelihoods of local communities. Despite these uncertainties, large numbers of projects on different scales and with varying objectives have been implemented to develop viable bioenergy cropping systems. A study by GEXSI identified 242 projects in 55 countries [3]. In 2008, this study projected that the total global area under jatropha cultivation would grow to 5 million ha in 2010. This was at a time when jatropha was receiving a great deal of attention and this projection raised high expectations. Later studies lowered the expectations, for example Achten et al. [4] and GTZ [5], or were even quite negative, such as Kant and Wu [6]. At the same time socio-economic and environmental sustainability issues for biofuels were becoming more important, as evidenced by, for example, the formulation of criteria by both the Roundtable on Sustainable Biofuels (RSB) and the Global Bioenergy Partnership (GBEP) [7].

The focus on the viability and sustainability of jatropha as an energy crop has led to an increasing number of research publications, project results and experiences of different aspects of the jatropha value chain in various reports. These publications focus on different aspects, for example on cultivation [8–10], processing and technical properties [11–15], market prospects [16], and the impact on the environment [17,18]. In addition, different business models and impacts on farming systems have been assessed [19,20], as well as the impact of the policy environment [21]. Some publications describe a certain aspect of the value chain, whereas others focus on a specific country (such as Mshandete [22], and Liu et al. [23], focusing on Tanzania and China, respectively) or on one business model (for example Brittaine and Lutaladio [24], who focused on smallholders). Furthermore, Carels [25] published a review including agronomical and technological aspects, while Abdulla et al. [26] compiled a review on technical issues only. In addition to being heterogeneous, a large share of the literature is based on secondary sources that are not necessarily accurate and lag behind the fast-changing realities on the ground. The jatropha sector is dynamic: many new projects are starting up while others are being discontinued. Both successes and failures could provide valuable lessons if analysed systematically.

The objective of this paper is to provide a comprehensive overview of recent literature based on information from ongoing and discontinued jatropha projects, which analyses the lessons learned so far and identifies knowledge gaps by evaluating and screening against generally agreed socioeconomic and environmental sustainability criteria. Although agronomy and technology are important aspects in jatropha cultivation and processing, these aspects are not part of a sustainability framework such as RSB or GBEP. However, they are essential for increasing the efficiency of the cropping system and thus the various impacts. Several studies have taken the technical aspects into account, such as Silitonga et al. [27] and Shahid and Jamal [28]. The main conclusion from these studies was that it is technically possible to use jatropha biofuel in diesel engines. However, more research is required to gain better insight into the lifetime of the engine. The agronomic aspects are currently being studied in long-term projects such as [29,30]. Knowledge gaps on agronomy issues are reviewed in [31].

This paper starts with an overview of the global jatropha sector (Section 2); subsequently, the aspects included in the review are discussed (Section 3). Section 4 presents an overview of the studies used and Section 5 provides details on the analysis of these studies. Knowledge gaps are identified in Section 6 and lastly conclusions (Section 7) and recommendations (Section 8) are provided. Throughout this assessment, the term *jatropha oil* is used for both jatropha biodiesel and jatropha Straight Vegetable Oil (SVO); some studies refer to jatropha biodiesel as Jatropha Methyl Ester (JME).

2. Status of jatropha projects/overview of the sector

In 2008, 242 jatropha projects were identified as carried out or about to be carried out, around the world. These were both small-

[1] Intergovernmental Panel on Climate Change.